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LIQUID CRYSTAL DISPLAY DEVICE

BACKGROUND OF THE INVENTION

1. FIELD OF THE INVENTION

The present invention relates to a display device, and more particularly, to an active-matrix type liquid crystal display device.

2. DESCRIPTION OF THE RELATED ART

In an active-matrix type liquid crystal display device, on a liquid-crystal-side surface of one of respective substrates which face each other in an opposed manner with liquid crystal, therebetween, for example, gate signal lines which extend in the x direction and are arranged in parallel in the y direction, and drain signal lines which extend in the y direction and are arranged in parallel in the x direction are formed. Regions which are surrounded by these respective signal lines constitute pixel regions, and a mass of these respective pixel regions arranged in a matrix array forms, a liquid crystal display part.

Here, each pixel region includes a switching element which is driven in response to a scanning signal from one gate signal line and a pixel electrode to which a video signal is supplied from one drain signal line through the switching element.

The pixel electrode generates an electric field between the pixel electrode and a counter electrode, which is formed on the above-mentioned one substrate or emother substrate and

the optical transmissivity of the liquid crystal is controlled based on the electric field.

The optical transmissivity of the liquid crystal is determined based on an amount of potential difference (gray scale) of the video signal (voltage) applied to the pixel electrode with respect to the reference signal (voltage) applied to a counter electrode. Here, for example, for preventing polarization of the liquid crystal, there has been known method which generates a positive-side gray scale voltage and a negative-side gray scale voltage with respect to the above-mentioned video signal, and applies these gray scale voltages alternately, for example.

In such a pixel driving, while there has been known amethod in which accenter voltage of the video signal is always fixed irrespective of amplitude of the signal as shown in Fig. 12 has been also known a method in which the center voltage of the video signal is decreased corresponding to the increase of the amplitude of the signal as shown in Fig. 12 has been applicated as shown in Fig. 12 has been also known a method in which the center voltage of the video signal is decreased corresponding to the increase of the amplitude of the signal as shown in Fig. 12 has been applicated as a shown in Fig. 12 has been app

That is, the pixel is configured to be driven by forming the respective gray scale voltages such that an average value of the positive-side gray scale voltage and the negative-side gray scale voltage is increased with respect to the reference signal supplied to the counter electrode along with decrease the signal amplitude of the video signal (see Japanese

Unexamined Patent Publication Hei7(1995)-92937 (patent literature 1)).

BRIEF SUMMARY OF THE INVENTION

However, in the liquid crystal display device having such a constitution, when the signal amplitude of the video signal is switched between the maximum and the minimum, to be more specific, when the display is switched from black to white or from white to black, as can be readily understood from the drawing, the large difference arises between the center voltage before switching and the center voltage after switching.

This implies that when the observation is made in view of a state after switching, the state is equivalent to a state in which a DC current is applied between the pixel electrode of the pixel and the counter electrode until a point immediately before switching.

After switching, the center voltage suitable as a value after switching is applied by a switching element; and hence, there exists no DC current between the pixel electrode of the pixel and the counter electrode. However, the response of liquid crystal molecules in response to the change requires several tens, ms; and, hence, the above-mentioned influence of the DC current remains optically until the completion of the response.

Accordingly, there arises a phenomenon that the apparent

response speed is delayed due to the influence of the DC voltage.

The present invention has been made under such circumstances, and it is an advantage of the present invention to provide a display device which can enhance a presponse speed.

invention disclosed in this specification are as follows.

A display device according to the present invention for example includes a pixel electrode to which a video signal is supplied and a counter electrode to which a reference signal, which becomes the reference with respect to the video signal, is supplied in each pixel, wherein

a positive-side gray scale voltage and a negative-side gray scale voltage are formed with respect to the reference signal applied to the counter electrode such that

and the negative-side gray scale voltage is increased when a signal amplitude of the video signal falls in a range from a minimum value to a first value,

(b) the average value of the positive-side gray scale voltage and the negative-side gray scale voltage is decreased when the signal amplitude of the video signal falls in a range from the first value to a second value, and

(c)the average value of the positive-side gray scale voltage and the negative-side gray scale voltage is increased when the

signal amplitude of the video signal falls in a range from the second value to a maximum value.

Example
Means, 2.

The display device according to the present invention is, for example, on the premise of the constitution of means, and the negative-side gray scale voltage and the negative-side gray scale voltage with respect to the signal amplitude of the video signal assumes an upper extreme point at a point where the average value changes from the increase to the decrease, and, a lower extreme point at a point where the average value changes to the decrease and the increase to the decrease and the increase to the decrease and the decrease to the increase in the range from the minimum value to the maximum value of the signal amplitude of the video signal.

The display device according to the present invention is, for example, on the premise of the constitution of means 2, characterized in that the average value of the positive-side gray scale voltage and the negative-side gray scale voltage with respect to the signal amplitude of the video signal which reaches the lower extreme point from the upper extreme point is changed monotonously.

The display device according to the present invention is, fer example, on the premise of the constitution of means.

2, characterized in that the average value of the positive-side

gray scale voltage and the negative-side gray scale voltage with respect to the signal amplitude of the video signal is changed monotonously from the minimum value to the upper extreme point of the signal amplitude of the video signal and from the lower extreme point to the maximum value of the signal amplitude of the video signal.

Eurple

The display device according to the present invention is, for example, on the premise of the constitution of means, 4, characterized in that the average value of the positive-side gray scale voltage and the negative-side gray scale voltage of the signal amplitude of the video signal at the minimum signal amplitude of the video signal is smaller than the average value of the positive-side gray scale voltage and the negative-side gray scale voltage of the signal amplitude of the video signal at the lower extreme point.

The display device according to the present invention is, for example, on the premise of the constitution of means 4, characterized in that the average value of the positive-side gray scale voltage and the negative-side gray scale voltage of the signal amplitude of the video signal at the maximum signal amplitude of the video signal is larger than the average value of the positive-side gray scale voltage and the negative-side gray scale voltage of the signal amplitude of the video signal

at the upper extreme point. Example 7.

A display device according to the present invention, for includes a pixel electrode to which a video signal is supplied and a counter electrode to which a reference signal which becomes the reference with respect to the video signal is supplied in each pixel, wherein

gray scale voltage are formed with respect to the reference signal applied to the counter electrode such that

(a) an average value of the positive-side gray scale voltage and the negative-side gray scale voltage is increased when a display gray scale of the video signal falls in a range from a minimum value to a first value,

(b) the average value of the positive-side gray scale voltage and the negative-side gray scale voltage is decreased when the signal amplitude of the video signal falls in a range from the first value to a second value, and

c) the average value of the positive-side gray scale voltage and the negative-side gray scale voltage is increased when the display gray scale of the video signal falls in a range from the second value to a maximum value.

The display device according to the present invention is, for the premise of the constitution of means,

7, characterized in that the average value of the positive-side gray scale voltage gray scale voltage with respect to the signal amplitude of the video signal assumes an upper extreme point at a point where the average value changes from the increase to the decrease and a lower extreme point at a point where the average value changes from the increase to the decrease and a lower extreme point at a point where the average value changes from the decrease to the increase in the range from the minimum value to the maximum value of the display gray scale of the video signal.

The display device according to the present invention is, for example on the premise of the constitution of means, 8, characterized in that the average value of the positive-side gray scale voltage and the negative-side gray scale voltage with respect to the signal amplitude of the video signal which reaches the lower extreme point from the upper extreme point is changed monotonously.

The display device according to the present invention is, for example on the premise of the constitution of means 9, characterized in that the average value of the positive-side gray scale voltage and the negative-side gray scale voltage of the signal amplitude of the video signal at the minimum display gray scale of the video signal is smaller than the average value of the positive-side gray scale voltage and the negative-side gray scale voltage of the signal amplitude of the video signal

at the lower extreme point. Eurole Means, 11.

The display device according to the present invention is, for example, on the premise of the constitution of means, 9, characterized in that the average value of the positive-side gray scale voltage and the negative-side gray scale voltage of the signal amplitude of the video signal at the maximum display gray scale of the video signal is larger than the average value of the positive-side gray scale voltage and the negative-side gray scale voltage of the signal amplitude of the video signal at the upper extreme point.

The display device according to the present invention is, for example on the premise of the constitution of means, 11, characterized in that the display device is driven in a normally white mode in which the minimum of the display gray scale assumes a white display and the maximum of the display gray scale assumes a black display.

The display device according to the present invention is, for example) on the premise of the constitution of means, and the display device is driven in a normally black mode in which the minimum of the display gray scale assumes a black display and the maximum of the display gray gray scale assumes a white display.

Example 14.

A display device according to the present invention, for example, includes a pixel electrode to which a video signal is supplied and a counter electrode to which a reference signal, which becomes the reference with respect to the video signal is supplied in each pixel, wherein

with respect to the reference signal which is applied to the counter electrode,

along with the increase changemplitude of the video signal functions.

voltage, a positive-polarity voltage of the video signal includes at least two points of inflection, such that the positive-polarity voltage is sharply increased, is gradually increased and is again sharply increased, and a negative-polarity voltage of the video signal includes at least two points of inflection, such that the negative-polarity voltage is gently decreased, is sharply decreased and is again gently decreased.

Example 15.

A display device according to the present invention, for example, includes a pixel electrode to which a video signal is supplied and a counter electrode to which a reference signal, which becomes the reference with respect to the video signal is supplied in each pixel, wherein

along with the increase a gray scale to be displayed,

a positive-polarity voltage of the video signal includes at

least two points of inflection such that the positive-polarity voltage is sharply increased, is gradually increased and is again sharply increased, and a negative-polarity voltage of the video signal includes at least two points of inflection, such that the negative-polarity voltage is gently decreased, is sharply decreased and is again gently decreased.

Example Means 16.

The display device according to the present invention is, for example, on the premise of the constitution of either one of means 1 or 7, characterized in that a circuit which forms the respective gray scale voltages includes gray scale division resistances and these resistances are constituted of seven or more resistances.

Example 17.

The display device according to the present invention is, for example, on the premise of the constitution of means 16, characterized in that a resultant resistance of the gray scale voltages between positive-polarity voltage outputs is total set larger than a resultant resistance of the gray scale voltages between negative-polarity voltage outputs.

Example Means 18.

A driving method of a display device according to the present invention, for example, which includes a pixel electrode to which a video signal is supplied and a counter electrode to which a reference signal which becomes

respect to the video signal is supplied in each pixel, wherein

a positive-side gray scale voltage and a negative-side gray scale voltage are formed with respect to the reference signal applied to the counter electrode such that

and the negative-side gray scale voltage is increased when a signal amplitude of the video signal falls in a range from a minimum value to a first value,

(b) the average value of the positive-side gray scale voltage and the negative-side gray scale voltage is decreased when the signal amplitude of the video signal falls in a range from the first value to a second value, and

the average value of the positive-side gray scale voltage and the negative-side gray scale voltage is increased when the signal amplitude of the video signal falls in a range from the second value to a maximum value.

The present invention is not limited to the above-mentioned constitutions and various modifications are conceivable without departing from the technical concept of the present invention.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a graph A showing one embodiment of the relationship between a signal amplitude of a video signal and a center voltage (an average value of a positive-side gray scale

voltage and a negative-side gray scale voltage) of the video one substituted signal of a display device according to the present invention;

Fig. 2 is a graph showing the relationship between the signal amplitude of the video signal and the display brightness of the display device according to the present invention;

Fig. 3 is a graph showing another embodiment of the relationship between the signal amplitude of the video signal and the center voltage (the average value of the positive-side gray scale voltage and the negative-side gray scale voltage) of the video signal of the display device according to the present invention;

Fig. 4 is a timing chart showing the video signal (having the positive-side gray scale voltage and the negative-side gray scale voltage), a scanning signal and a reference signal supplied to pixels of the display device according to the present invention;

Fig. 5 is a circuit diagram showing one embodiment of a resistance voltage divider circuit provided to a latter stage of a gray scale generating circuit provided to the display device according to the present invention;

Fig. 6 is a graph showing one embodiment of a video signal (having a positive-side gray scale voltage and a negative-side gray scale voltage) supplied to pixels of the display device according to the present invention in view of the relationship thereof with a display gray scale of the video signal;

Fig. 7 is a table showing one embodiment of respective resistance values of the resistance divider circuit in the latter stage of the gray scale generating circuit provided to the display device according to the present invention, gray scale voltages obtained from the resistance voltage divider circuit and the center voltage of the video signal;

Fig. 8A is an equivalent circuit diagram showing one embodiment of the display device according to the present just Fig.8B is a went diagram of a representative push region B in Fig.8A invention;

Fig.9 is a constitutional view, showing one embodiment of the pixel of the display device according to the present invention;

Fig. 10 is a constitutional view showing another embodiment of the pixel of the display device according to the present invention;

Fig. 11 is a constitutional view showing one embodiment of a pixel of a liquid crystal display device according to the present invention; and

Fip 12 A and 12 B an graph, showing an example of the relationship between a signal amplitude of a video signal and a center voltage of the video signal of a conventional liquid crystal display device.

DETAILED DESCRIPTION OF THE INVENTION

Embodiments of a display device according to the present

invention are Aexplained in conjunction with Adrawings hereinafter.

Embodiment 1.

<<Overall equivalent circuit>>

Fig. 8Ais an equivalent circuit diagram showing one embodiment of a display device (a liquid crystal display device in this embodiment) according to the present invention.

Although the drawing is the equivalent circuit diagram, it is depicted in accordance with an actual arithmetic arrangement of the circuit of the display device.

The display device includes a pair of transparent substrates SUB1, SUB2 which are arranged to face each other matural disposed in an opposed manner with liquid crystal therebetween, wherein the liquid crystal is sealed by a sealing material SL, which also performs affunction of fixing another transparent substrate SUB2 to energy transparent substrate SUB1.

On a liquid-crystal-side surface of encytransparent substrate SUBL which is surrounded by the sealing material SL, gate signal lines GL which extend in the x direction and are arranged in parallel in the y direction and drain signal lines DL which extend in the y direction and are arranged in parallel in the x direction are formed.

Regions which are surrounded by the respective gate signal lines GL and the respective drain signal lines DL constitute pixel regions and a mass of these respective pixel regions in

soast

a matrix array constitute a liquid crystal display part AR.

Further, in the respective pixel regions which are arranged in parallel in the x direction, a common counter voltage signal line CL, which runs in the inside of the respective pixel regions, is formed. The counter voltage signal line CL constitutes a signal line for supplying a voltage, which becomes the reference with respect to a video signal, to a counter electrode CT of the pixel region described later.

In each pixel region, a thin film transistor TFT, which is driven in response to a scanning signal from the one-side gate signal line GL, and a pixel electrode PX to which a video signal is supplied from the one-side drain signal line DL via this thin film transistor TFT are formed.

This pixel electrode PX generates an electric field, between the pixel electrode PX and a counter electrode CT which is connected to the counter voltage signal line CL and controls the optical transmissivity of the liquid crystal in response to the electric field.

Here, a capacitive element Cstg is formed between the pixel electrode PX and the counter voltage signal line CL and a video signal which is supplied to the pixel electrode PX is held for a relatively long time due to this capacitive element Cstg.

Respective ends of the above-mentioned gate signal lines ${
m GL}$ extend beyond the above-mentioned sealing material ${
m SL}_j$ and

the extended ends thereof form terminals GLT to which output terminals of the scanning signal drive circuit V are connected. Further, to input terminal of the scanning signal drive circuit V, a signal from a printed circuit board (not shown in the drawing) which is arranged outside the liquid crystal display panel is inputted.

The scanning signal drive circuit V is formed of a plurality of semiconductor devices. Applurality of gate signal lines GL which are arranged close to each other are formed into a group, and one semiconductor device is allocated to each group of gate signal lines GL.

In the same manner, respective ends of the drain signal line DL extend beyond the sealing material SL and the extended ends constitute terminals DLT to which output terminals of the video signal drive circuit He are connected. Further, to input terminals of the video signal drive circuit He, a signal from a printed circuit board (not shown in the drawing) which is arranged outside the liquid crystal display panel is inputted.

The video signal drive circuit He is also formed of a plurality of semiconductor devices. A plurality of drain signal lines DL which are arranged close to each other are formed into a group and one semiconductor device is allocated to each group of drain signal lines DL. Further, the counter voltage signal lines CL are connected in common to a connection line at the right side in the drawing and the connection line

extends beyond the sealing material SL and constitutes a terminal CLT at an extended end thereof. From the terminal CLT, a voltage which becomes the reference with respect to the video signal is supplied to the pixels.

The respective gate signal lines GL are selected sequentially one after another in response to the scanning signal from the scanning signal drive circuit V.

Further, to respective drain signal lines DL, the video signal is supplied from the video signal drive circuit He at the timing of selecting the gate signal lines GL.

In the above-mentioned embodiment, the scanning signal drive circuit V and the video signal drive circuit He are constituted of semiconductor devices which are mounted on the transparent substrate SUB1. However, the scanning signal drive circuit V and the video signal drive circuit He may be formed of semiconductor devices as so-called tape carrier method, which are connected to each other while striding over the transparent substrate SUB1 and a printed circuit board, for example. Alternatively, when a semiconductor layer of the thin film transistor TFT is formed of a polycrystalline silicon (p-Si), semiconductor elements made of polycrystalline silicon may be formed on a surface of the transparent substrate SUB1 together with wiring layers.

<< Constitution of pixel >>

Fig. 9 (1) is a plan view showing one embodiment of the

specific constitution of the above-mentioned pixel, Fig. 9(b) is a cross-sectional view taken along a line b-b in Fig. 9(a), and Fig. 9(c) is a cross-sectional view taken along a line c-c in Fig. 9(a).

First of all, on a liquid-crystal-side surface of the Hours
transparent substrate SUB1, a semiconductor layer LTPS formed
of a polysilicon layer, for example is formed. The
semiconductor layer LTPS is formed by polycrystalizing an
amorphous Si film formed by a plasma CVD device, for example,
using an excimer laser.

The semiconductor layer LTPS is a semiconductor layer of the thin film transistor TFT and is formed in a roundabout manner such that the semiconductor layer LTPS traverses the gate signal line GL described later twice.

Further, on the surface of the transparent substrate SUB1 on which the semiconductor layers LTPS formed, a first insulation film INS made of SiO₂ or SiN, for example, is formed such that the first insulation film INS also covers the LTPS semiconductor layers The first insulation film INS is configured to function as gate insulation film of the thin film transistor. TFT.

Further, on an upper surface of the first insulation film INS, the gate signal lines GL which extend in the x direction and are arranged in parallel in the y direction in the drawing are formed and the gate signal lines GL define rectangular pixel

regions together with the drain signal lines DL described later.

The gate signal lines GL are configured to run such that the gate signal lines GL traverse the semiconductor layer LTPS twice, and portions of the gate signal lines GL which traverse the semiconductor layer LTPS function as gate electrodes of the thin film transistor TFT.

After the formation of the gate signal lines GL, impurities ions are implanted by way of the first insulation film INS so as to make regions of the semiconductor layer LTPS except for a region right below the gate signal line GL conductive thus forming a source region and a drain region of the thin film transistor TFT.

Further, on an upper surface of the first insulation film INS, counter electrodes CT are formed. With respect to the counter electrodes CT, for example, two strip-like electrodes which extend in the y direction in the drawing are arranged close to the drain signal lines DL described later in the pixel. These respective counter electrodes CT are integrally formed with a counter voltage signal line CL which runs in the x direction in the drawing at the substantially center of the pixel, and the reference signal is supplied through the counter voltage signal line CL.

Further, on the upper surface of the above-mentioned first insulation film INS, a second insulation film which is made of SiO_2 or SiN, for example, is formed such that the second

insulation film GI also covers the gate signal lines GL and the counter electrodes CT (counter voltage signal lines CL).

On a surface of the second insulation film GI, the drain signal lines DL which extend in the y direction and are arranged in parallel in the x direction are formed. Then, portions of the drain signal lines DL are connected to the above-mentioned semiconductor layer LTPS via through holes TH1 which penetrate the second insulation film GI and the first insulation film INS disposed below the drain signal lines DL. Portions of the semiconductor layer LTPS which are connected with the drain signal lines DL are portions which constitute one region, for example, drain regions of the thin film transistor TFT.

On the surface of the second insulation film GI, a third insulation film PAS is formed such that the third insulation film PAS also covers the drain signal lines DL. On a surface of the third insulation film PAS, pixel electrodes PX are formed. These pixel electrodes PX are formed of strip-like electrodes which extend in the y direction in the drawing at the center of the pixels and hence, the pixel electrode PX is positioned between the above-mentioned respective counter electrodes CT. The pixel electrode PX has a portion thereof connected with another region, for example, a source region of the thin film transistor TFT, via a through hole TH2 which is formed in the third insulation film PAS, the second insulation film GI and the first insulation film INS disposed below the pixel electrode

in a penetrating manner.

Here, the pixel electrode PX is formed to have a large width at a portion thereof which intersects the counter voltage signal line CL and a capacitive element Cstg is formed between the pixel electrode PX and the counter voltage signal line CL at the portion.

Electric fields which have components parallel to the transparent substrate SUB1 are generated between the pixel electrode PX and the respective counter electrodes, which are respectively positioned at both sides of the pixel electrode PX, and the optical transmissivity of the liquid crystal can be controlled due to these electric fields.

Here, the pixel electrode PX is, in this first embodiment, formed of a light-transmitting conductive layer, such as ITO (Indium Tin Oxide), ITZO (Indium Tin Zinc Oxide), IZO (Indium Zinc Oxide), SnO₂ (Tin Oxide), In₂O₃ (Indium Oxide), for example, for enhancing in numerical aperture.

electrodes PX are formed on the upper surface of the third insulation film PAS. However, it is needless to say that, as shown in Fig. 9 (d), the pixel electrodes PX may be formed below the third insulation film PAS, that is, on the same layer as the drain signal lines DL. This is because that the substantially same advantageous effects can be obtained.

Fig. 1 is a characteristic graph showing the center voltage which is changed in response to the magnitude of unamplitude of the video signal supplied to the respective drain signal lines DL of the liquid crystal display device according to the present invention, and secreesponds to Fig. 12800.

In the characteristic graph shown in Fig. 1, the amplitude of the video signal is taken on an axis of abscissas such that the amplitude assumes a minimum value at the left side in the drawing and a maximum value at the right side in the drawing and the center voltage of the video signal is taken on an axis of ordinates. Here, the center voltage of the video signal constitutes means an average value of the positive-side gray scale voltage and the negative-side gray scale voltage of the video signal.

The center voltage of the video signal, first of all, assumes a certain value "a" when the amplitude of the video signal assumes the minimum value and is increased corresponding to the increase of the amplitude of the video signal to a first value, thus assuming a certain value "b". Then, the center voltage of the video signal is decreased corresponding to increase of the amplitude of the video signal to a second value. Then, when the center voltage of the video signal arrives at a certain value "c", the center voltage of the video signal is increased to reach the certain value "a" or a value which is close to the value "a". In other words, the center voltage of the video signal at the minimum amplitude value is set to